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Effects of perceptual depth cues on movement time in a target acquisition task

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EFFECTS OF PERCEPTUAL DEPTH CUES ON MOVEMENT TIME IN A TARGET ACQUISITION TASK

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ABSTRACT

EFFECTS OF PERCEPTUAL DEPTH CUES ON MOVEMENT TIME IN A TARGET ACQUISITION TASK

By Audra J. Ruthruff

Visual display researchers have often studied the ability of a human operator to use a movement device to capture a target in a visual array. The present study builds on previous research on the effects of 3-dimensional (3-D) depth cues within 2-D displays (Raddatz, Uhlarik, & Jordan, 2001), the visual-motor processes involved (Goodale & Milner, 1992), and how Fitts' Law models movements (e.g., Graham & MacKenzie, 1996; Jagacinski, 1989). The present study specifically sought to determine whether the distance variable in Fitts' movement time (MT) equation is best modeled using proximal distance or the perceived distance produced by the 3-D cues of linear perspective and foreshortening. Results indicate that movements to acquire targets within our displays were based on the proximal distance, and this suggests a dissociation between the visual perception of objects and the guided actions to acquire them within a virtual array.

ACKNOWLEDGMENTS

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The ability of a human operator to use a movement device to capture a target in a visual array is a fundamental issue in human performance research. The response or movement times are of particular interest when studying the perceptual-motor processes involved in target acquisition tasks. Target acquisition tasks are utilized in a multitude of real world settings including aviation and medicine. For example, in aviation settings, an air traffic controller must be able to point to a location or target on a visual display with both speed and accuracy in order to carry out functions related to the job of monitoring aircraft. Another example is the medical setting in which surgeons must accurately and efficiently manipulate a telerobotics device during microsurgery.

What is it about the visual display that affects motor coordination in target acquisition tasks like those of the air traffic controller or surgeon? Some of the current research has focused on the perception of the visual display information, in particular, the perception of three-dimensions (3-D) by using 3-D depth cues within the two-dimensional (2-D) virtual environment. For example, perspective depth cues have been shown to be useful in supporting veridical size judgments within virtual displays (Raddatz, Uhlarik, & Jordan, 2001). Also, Liao and Johnson (under review) examined the effects of drop-lines in a 3-D perspective display. They found that drop-lines aided the perceptual-motor performance in a target acquisition task using 3-D navigation.

Additional research has focused on the separate processing pathways of visual perception and motor movements (Brenner & Smeets, 1996; Westwood, Dubrowski, Carnahan, & Roy, 2000). This literature suggests that visual perception is processed in the ventral pathways of the cortex, while the motor actions are guided by the dorsal pathways (Goodale & Milner, 1992). However, not all research findings are consistent with this notion that all motor movements are separate from visual processing (Brenner & Smeets, 1996; Donkelaar, 1999; Westwood, Dubrowski, Carnahan, & Roy, 2000).

Examination of movement times in target acquisition tasks have been widely studied using the Fitts' Law model. Fitts' Law was developed as a predictor of the speed-accuracy trade off in discrete, rapid aimed movements. The original studies involved tapping motions using a stylus device (Fitts, 1954). However, more recent research suggests that Fitts' Law is also a useful predictor in cursor-controlled pointing tasks (Boritz, Booth, & Cowan, 1991; Card, English & Burr, 1978; Epps, 1986).

To further advance research on the coordination of perceptual-motor tasks within virtual displays, the present study investigated the effects of 3-D perspective cues on movement time using Fitts' Law in a target acquisition task.

3-D Perspective Cues

In most real world environments, we utilize perspective cues to depth in order to interact with our surroundings. Some of these depth cues include height in the plane, relative size, texture gradient, interposition, linear perspective, and foreshortening. Two of these cues, linear perspective and foreshortening, have been shown to be particularly accurate and effective cues to depth (Raddatz, Uhlarik, & Jordan 2001; see Figure 1). Linear perspective is a set of radiating lines that converge toward an apex in a depth

Definitions

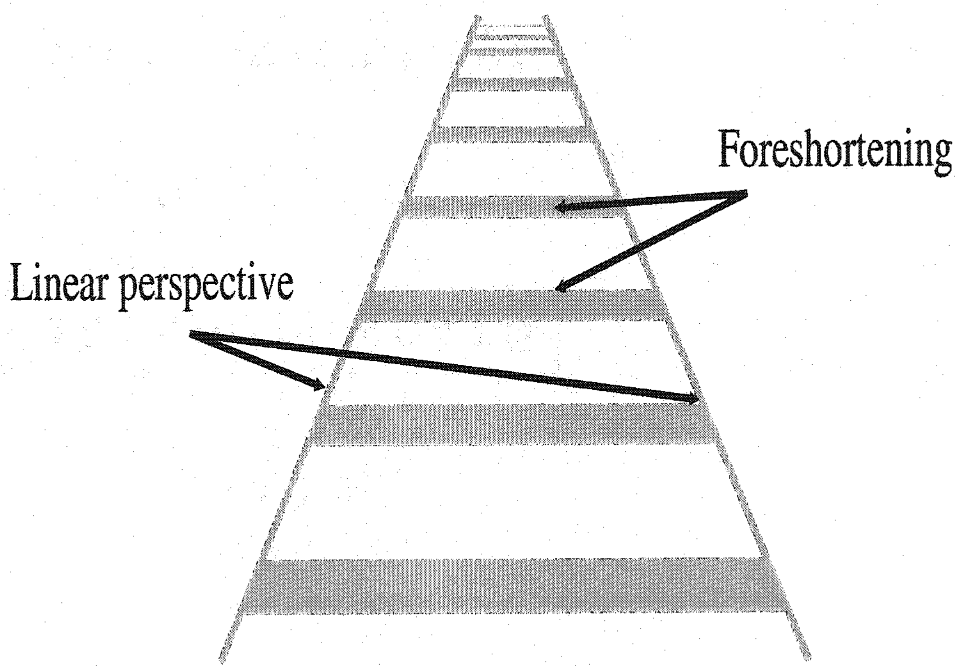

Figure 1. Example of linear perspective and foreshortening.

plane, similar to what you would see when looking at train tracks receding in the distance. Foreshortening is the depth cue created when multiple parallel lines (usually horizontal) fall progressively closer together as they extend toward a horizon line.

In the real world, we use these 3-D cues to help us to judge the size of objects and their distance from us. In judging objects in the real world, humans are able to maintain size constancy, which is the ability to correctly perceive the size of an object despite any changes in the viewing distance and retinal size of the object. However, this perception of size in the real world becomes inaccurate when transferred to a 2-D computer display, creating visual illusions. That is, two objects of the same retinal size set into an array of 3-D cues may "appear" to be different size objects. Research has shown that size constancy can be maintained using 3-D cues on a 2-D visual display. Raddatz, Uhlarik, and Jordan (2001) found that participants were able to maintain size constancy in a visual display using the 3-D cues of linear perspective and foreshortening. Their judgments of the height and width of objects within these displays were independent of distance, indicating size constancy was maintained. Miller (1997) also reported that depth cue orientation also affects the magnitude of the perceived depth and object size. In examining the effect of linear perspective, Miller found that arrays with the apex of the lines toward the top produced greater perceived depth of a pictorially-far stimulus than arrays with the apex of the lines toward the bottom, right, or left.

Perceptual-Motor Processes

The identification of objects, including our perception of their size and distance is only one part of the equation. Another part is the motor processes involved in acquiring a target. Current literature indicates that these processes may be controlled in different areas of the brain.

Goodale and Milner (1992) suggest that the process of object identification occurs in the ventral-temporal pathways of the cortex, while localization of movement occurs in the dorsal-parietal pathways. If this dissociation really occurs between object identification and the motor movement, then 3-D depth cues may play a role only in the perception of the size and distance of objects, but not necessarily the motor processes. Marotta, Behrman, and Goodale (1997) examined the effects of the removal of binocular cues on grasping in patients with visual form agnosia. Their results indicate that grip aperture in agnosic patients is disrupted by the removal of binocular cues, and that pictorial cues are used to supplement information to control grip aperture only as a last resort. This finding supports the two pathway model and the dissociation between visual perception of objects and the corresponding motor movement. However, some contention regarding this dissociation exists among researchers. Some researchers have examined the effects of size or distance on the grasping of objects or pointing to targets. Donkelaar (1999) found that when using the Ebbinghaus or Tichener circles illusion, participants' pointing movements were affected such that they took longer to acquire targets that were perceptually smaller (similar to what would occur with a target that was physically smaller). Brenner and Smeets (1996) found that when using the Ponzo or railway-line illusion (similar to linear perspective), only part of the motor movement was affected. They found that the illusion influenced the force used to lift an object, but did not influence the grasp (i.e., the distance between the thumb and fingers). Westwood, Dubrowski, Carnahan, and Roy (2000) examined the effect of the Ponzo illusion on motor movements. They found that the illusion affected certain motor movements (peak grip aperture, peak grip force, and peak vertical wrist acceleration), while others did not show illusory size effects (movement time, and peak wrist velocity). The guidance of motor movements found in many of the studies of the dissociation between perception and action focused primarily on physical reaching or grasping. There seems to be a lack of investigation on the effect of virtual pointing or moving tasks within computer displays, and in particular, within displays using illusory depth cues.

Fitts' Law

In examining the perceptual and motor processes of the human operator, many researchers have used Fitts' Law to describe the movement time in pointing tasks (e.g., Graham & MacKenzie, 1996; Jagacinski, 1989; Jagacinski, Repperger, Moran, Ward, & Glass, 1980). In general terms, Fitts' Law is a model of the speed-accuracy trade off in the relationship among movement time, accuracy, target size, and distance to target. Specifically, it uses the size of the target and the distance to the target to determine an "index of difficulty" of the motor movement.

Fitts' Law is $MT = a + b (\log_2 2A/W)$, where "MT" is movement time, "a" (or the y-intercept) and "b" (or the slope) are mathematical constants, "A" is the amplitude or distance to the target, and "W" is the width or size of the target. The term "$\log_2 2A/W$" is often referred to as the index of difficulty (ID) measured in bits (see Fitts, 1954 for a complete description of the model).

According to the Fitts' Law model, the time for the capture of a target depends largely on the distance to the target and the size of the target. Thus, a larger ratio of 2A/W (i.e., a larger index of difficulty) corresponds to a longer acquisition time and greater relative accuracy. That is, a smaller target at a far distance takes longer to acquire than a larger target at a far distance.

Fitts' Law has been shown to be an accurate tool for examining interactions between humans and different types of movement devices, indexes of difficulty, angles of approach, and target shapes. For example, Epps (1986) studied the effects of six different cursor control devices including an absolute-mode touchpad, a relative-mode touchpad, an optical mouse, a trackball, a displacement joystick, and a force joystick, using the Fitts' Law model. He found that, although some devices such as the trackball and mouse were fit by the model better than other devices, Fitts' Law was successful at providing a predictor of performance for a wide array of cursor control devices.

Much of the previous literature using Fitts' Law as a model for determining movement time in target acquisition tasks has focused on either the target size or the distance to the target as the key variable in the equation (e.g., Boff & Lincoln, 1988a; Boff & Lincoln, 1988b; Kabbash & Buxton, 1995; Langolf, Chaffin, & Foulke, 1976). Further research has shown that other factors such as the angle of approach or trajectory (Jagacinski, Repperger, Moran, Ward & Glass, 1980; Whisenand & Emurian, 1996), and target shape (Sheikh & Hoffman, 1994), can also affect the Fitts' Law equation. Whisenand and Emurian (1996) found that angle of approach affected the movement time to capture a target. They found that movements in a diagonal direction were slower than horizontal and vertical movements.

Although both the target size and the distance to the target affect the time to execute the motor response, the present study investigated whether 3-D depth cues on a 2-D computer display also influences the movement time in target acquisition tasks. When we add 3-D depth cues to a 2-D surface, the question arises as to whether the observer perceives the proximal (or physical distance on the display surface) or distal (or perceived distance on the display) distance to the target. Furthermore, if perceived distance reflects the distal, rather than the proximal, properties of the array, we ask whether the distance variable in Fitts' Law (A) also reflects the distal properties of the array. If we perceive the distal properties of the array, then does this perception also affect the motor movements required in a target acquisition task? We propose that if these perspective cues really do affect the perception of visual stimuli, then presenting them on a display during a target acquisition task might change the relationship of the perceptual-motor response, and therefore the movement time of the Fitts' Law model.

Therefore, the present study examined the effects of display context on the movement time in the Fitts' Law model. In particular, the current experiment studied the effects of linear perspective and foreshortening depth cues on movement time during target acquisition tasks in a visual display. The hypotheses for the present study were as follows. By examining the relationship of the index of difficulty and movement time, we expected to determine whether observers perceive distance on these visual displays proximally (retinally), or distally (objectively). That is, if they perceived the distance proximally regardless of the depth cue condition, then movement times would be the same for linear perspective, foreshortening, and a control condition with no distance cue. However, if the distance was perceived distally, then movement times would differ across the various display conditions.

Of additional interest was whether movement times congruent with the geometry of the display would be greater than movement times orthogonal to the geometry of the display for both linear perspective and foreshortening. If these 3-D cues do induce greater perceived depth within the displays, then we would expect to see differences in movement times between movements congruent with the depth cues and movements against the cues.

For example, with the linear perspective depth cue pointing up towards the top of the display, a movement in the upward direction (i.e., congruent with the display) would have a greater movement time than a movement in a rightward direction (i.e., orthogonal to the display) because of the perception of greater distance within the display.

In addition, Gillam (1995) has suggested that linear perspective and foreshortening have different display geometries for calculating size and distance. These geometries are such that when focusing on the size of an object at a distance within linear perspective, it is found that size falls off as a function of the inverse of distance. That is, physical size is reduced as 1/d. Whereas, within foreshortening, the geometry of the display is such that the lines are perpendicular to the picture plane but parallel to the depth dimension. With foreshortening, size falls off as a function of distance squared (i.e., $1/d^2$). Therefore, it was expected that these differences in the geometries of the displays would affect movement times during a target acquisition task when based on the direction of movement relative to the display direction. If distal distance affects movement times in the congruent condition, the larger movement times would be expected in the foreshortening condition relative to the linear perspective condition based on the difference in the geometries of the displays.

Method

Participants

Thirty-two San Jose State University students participated in the study as partial fulfillment of a requirement in a general psychology course. Participants ranged in age from 18-35, and had normal or corrected to normal vision.

Stimuli & Apparatus

Participants were asked to use a trackball to move a cursor on an IBM compatible computer with an Intel Pentium processor. The trackball was used as the input device for the experiment based on Epps' (1986) findings, as well as pilot work that showed the trackball to be an efficient and accurate device for target acquisition tasks. The output display was a color CRT monitor with a 17-inch display with total pixels of 786 x 1064. In order to create equal visual displays, regardless of depth cue context, the experimental displays were limited to 786 x 786 pixels (or roughly $300mm^2$). The displays were rendered using World Construction Set software by 3D Nature. In addition, a C++ program was created to control the presentation of the stimuli, and record reaction times and movement times. The stimuli consisted of a delta symbol (e.g. "Δ") as a representation of the cursor to be moved, and circles as the targets. In the linear perspective condition, the computer screen displayed radiating lines converging from one side to the opposite side of the screen (similar to the real-world view of train tracks receding in the distance), (see Figure 2). The foreshortening condition consisted of a series of parallel lines located progressively closer together towards either the upper or right-hand portion of the screen (see Figure 3).

Design

The primary experimental design was composed of the two display conditions of linear perspective and foreshortening. Within the linear perspective and foreshortening conditions, there were two depth cue directions. The displays were designed such that greater distance was either perceived at the top or on the right of the computer screen. For example, within linear perspective, the width between the converging lines decreased either towards the top of the screen or towards the right of the screen. In foreshortening the height between the lines decreased towards the top of the screen or the right side of the screen.

In addition to the two display conditions, and the two depth cue directions, two movement directions were used. They consisted of a vertical movement from the bottom of the screen moving up towards the target, or a horizontal movement starting on the left side of the screen and moving right towards the target.

The final variables manipulated were the size of the target and distance from the cursor to the target. Manipulation of the size and distance variables was the index of difficulty (ID) portion of Fitts' Law described earlier. The study included two target

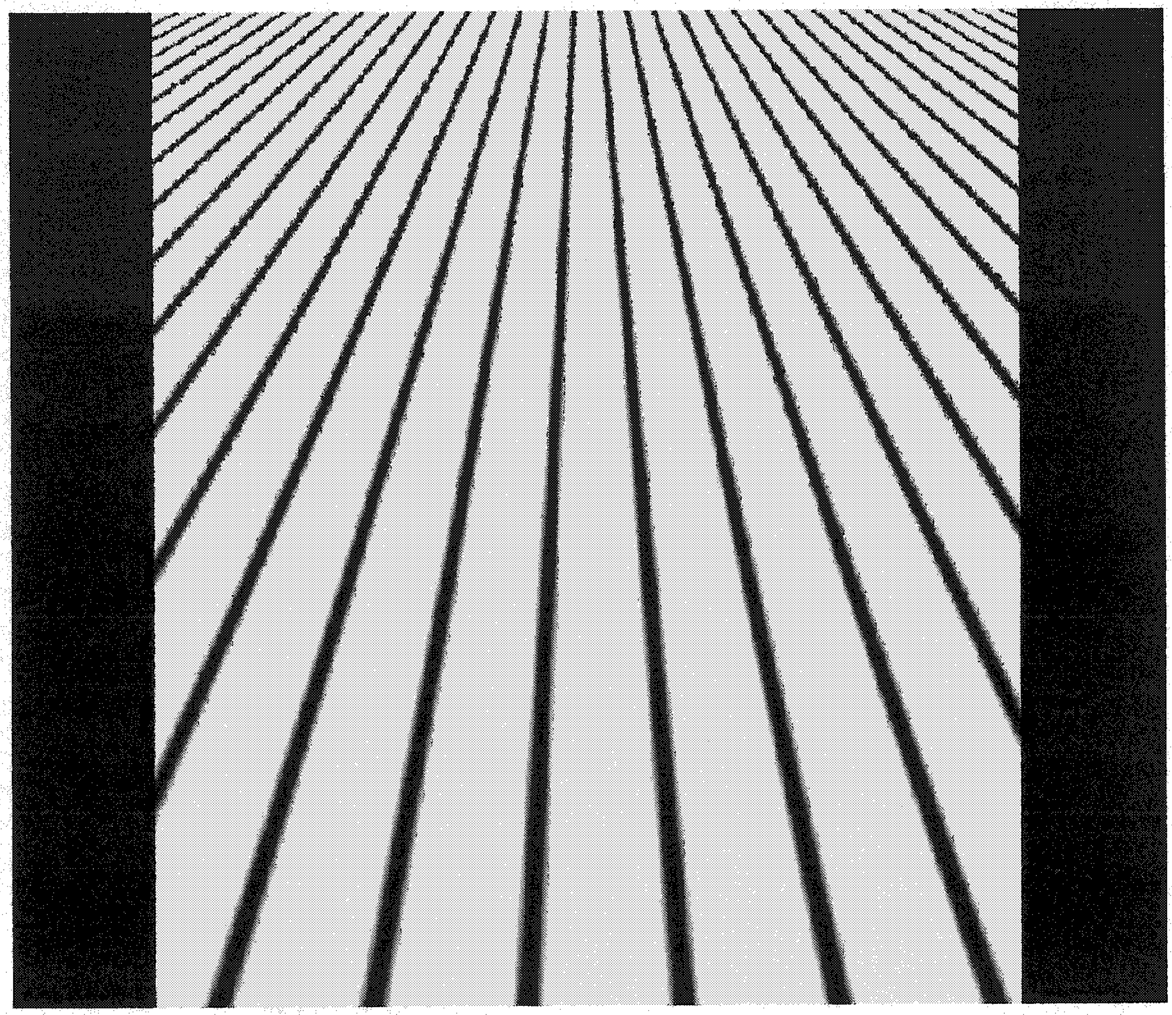

Figure 2. Linear perspective display in upright position.

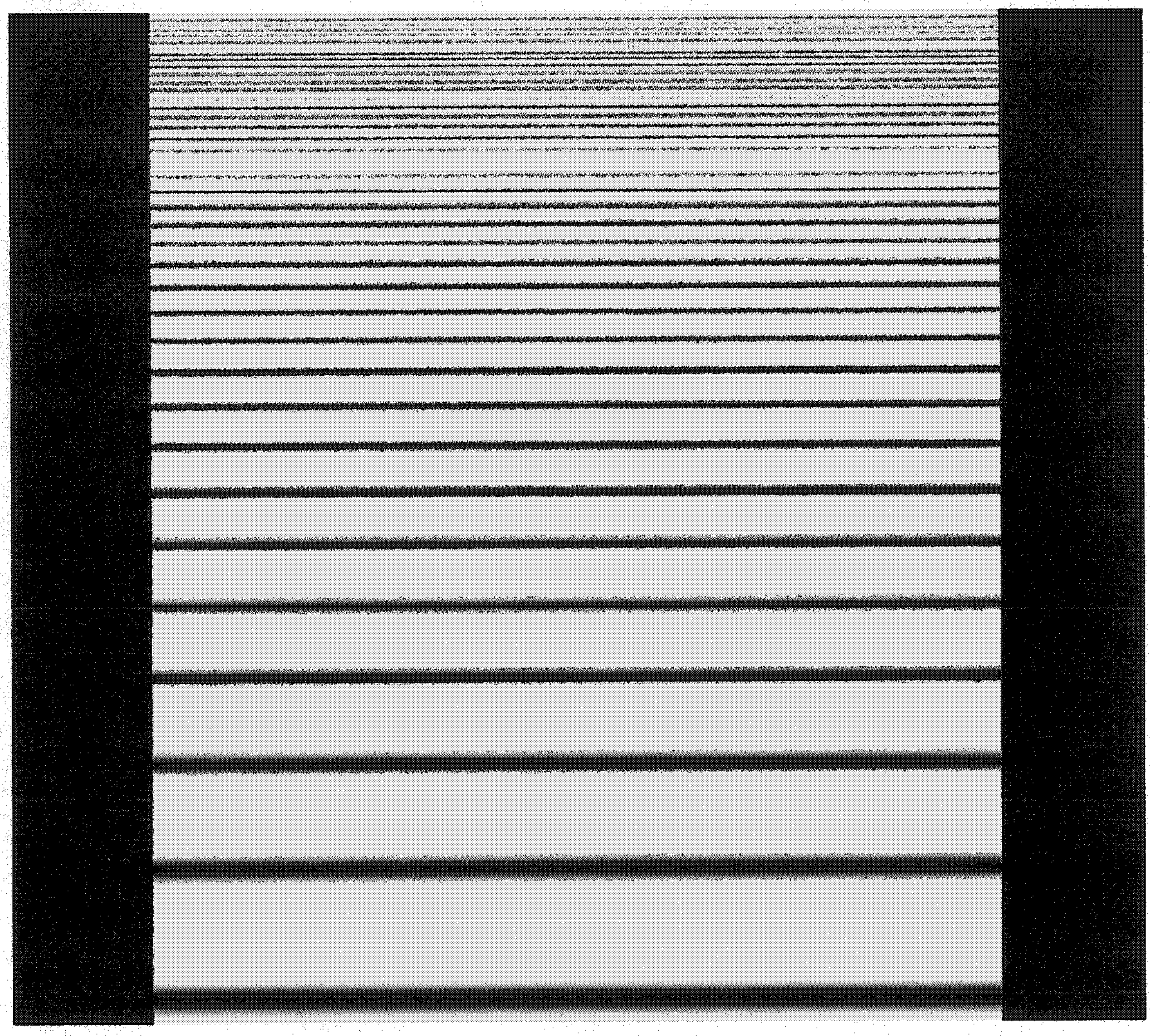

Figure 3. Foreshortening display in upright position.

sizes at three different distances for a total of 6 indices of difficulty according to the Fitts' Law model. The two target sizes displayed were an 18mm diameter circle and a 36mm diameter circle. The distances to the target were based on length from the bottom towards the top of the display or from the left towards the right side of the display, and were measured to the center of the target. The first distance was 60mm from the edge (i.e., bottom or left) to the center of the circle. The second distance was 170mm and the final distance was 250mm from the edge to the center of the target. As mentioned these two target sizes and three distances to the target resulted in six separate indices of difficulty ranging from 1.74 to 4.81 using the formula "$\log_2 2A/W$" (see Table 1).

The control condition contained a cursor and a target on an otherwise blank screen. The control condition included the two movement directions, two target sizes, and three distances to target (i.e., six indices of difficulty), similar to the primary experimental design. However, without explicit depth cues other than height in the plane (i.e., no display features) there was no manipulation of the depth cue direction.

The dependent variable of interest was movement time. Movement time was calculated as the time from initial appearance of the display with the cursor and target until the participant moved the cursor inside the target. The participant was required to maintain the cursor inside the target for one second to show that they had fully captured the target; however, the one second was not considered part of the movement time and was not included in the analyses.

Table 1.

Target Size, Distance to Target, and Fitts' Law Index of Difficulty (ID)

Size of Target (W) in millimeters	Distance to Target (A) in millimeters	Indices of Difficulty (ID) in bits per second ($\log_2 2A/W$)
18	60	2.75
36	60	1.74
18	170	4.25
36	170	3.25
18	250	4.81
36	250	3.81

Procedure

Each participant was tested individually. They were given a consent form with a brief explanation of the purpose of the experiment, notification of their ability to withdraw at anytime without penalty, and contact information should they have questions or concerns at the completion of the experiment. After they signed the consent form, they were given verbal instructions on how the experiment would proceed. They were told to use the trackball to move the cursor on the computer screen as quickly and as accurately as possible from the starting point to the target. To begin each block of trials the participant pressed a key on a keyboard.

Each movement direction was combined with each depth cue direction for all display conditions within a block of trials. Participants began by proceeding through a practice session consisting of 10 trials in which all five displays (i.e., control, foreshortening up, foreshortening right, linear perspective up, and linear perspective right) were presented once with each of the two movement directions (i.e., movement up, movement right). Following the practice trials, the participant proceeded through four blocks of 70 trials. To summarize the design, there were two display conditions, with two depth cue directions, two movement directions, and six indices of difficulty; for a total of 48 trials. In addition, there was a control condition, with two movement directions, and six indices of difficulty; for a total of 12 trials. In order to prevent motor programming of the movements, each block also contained 10 filler trials with two additional target sizes and three additional distances to targets. The combination of experimental, control, and filler trials resulted in the 70 trials per block. The order of the presentation of the trials was randomized within each block of trials. After the completion of all of the trials of the experiment, the participant was verbally given a debriefing with a complete explanation of the purpose of the study; they were given the opportunity to ask any questions, and thanked for their participation.

Results

To test the hypothesis that participant's movement times would vary across display conditions, based on whether they perceived distance proximally or distally, the experimental data was analyzed in a 3 (display condition: control, linear perspective, foreshortening) x 2 (direction condition: direct up, direct right) x 6 (indices of difficulty) within subjects analysis of variance. In collapsing across the direction condition factor, we used only congruent combinations of display direction and movement direction. For example, direct up is the congruent combination of display up with movement up; direct right is display right with movement right. In the analysis, the main question was whether or not the overall movement times varied for the six indices of difficulty, depending on the display condition and the direction condition. If observers responded to the proximal properties regardless of display condition, then movement times would be the same for linear perspective, foreshortening, and the control condition. However, if the distance was perceived distally, then movement times would differ across the display conditions. In particular, we would expect that across indices of difficulty, upward movements in the two depth cue display conditions (linear perspective and foreshortening) would differ from the control, whereas movements to the right would be the same for all three conditions. We found no significant interaction among the display condition, direction condition, and index of difficulty [F (10,22) = 0.86, p>.05]. Figure 4 shows the mean movement times for the three display conditions at each index of difficulty for movement and display direction up. Figure 5 shows the mean movement times for the three display conditions (linear perspective, foreshortening, and control) at each index of difficulty for display and movement direction right.

Our analysis did show a direction condition by index of difficulty interaction [F (5, 27) = 7.41, p<.01]. Figure 6 shows the mean movement times for the interaction. In the post-hoc analysis we found that the easiest index of difficulty of 1.74, which was the 36mm target at a distance of 60mm, showed that movements up were significantly faster (M = 684.87) as compared to movements right (M = 738.02). The two most difficult indices of difficulty (4.25, the 18mm target size at the 170mm distance; and 4.81, the 18mm target at the 250mm distance) showed that rightward movements were significantly faster (M = 1364.30; M = 1653.01, respectively) than movements up (M = 1417.40; 1743.92, respectively). There were no significant differences in the remaining indices of difficulty.

In our analysis we found that the overall mean movement times for the three display conditions did not differ significantly [F (2, 30) = 1.95, p>.05]. The mean movement times were as follows; linear perspective (M = 1238.10), foreshortening (M = 1248.39), and control (M = 1234.09).

Additionally, we tested the hypothesis that movements congruent with the display would be longer than movements against the geometry of the display. We analyzed the data in a 2 (condition: linear perspective, foreshortening) x 2 (movement direction: up,

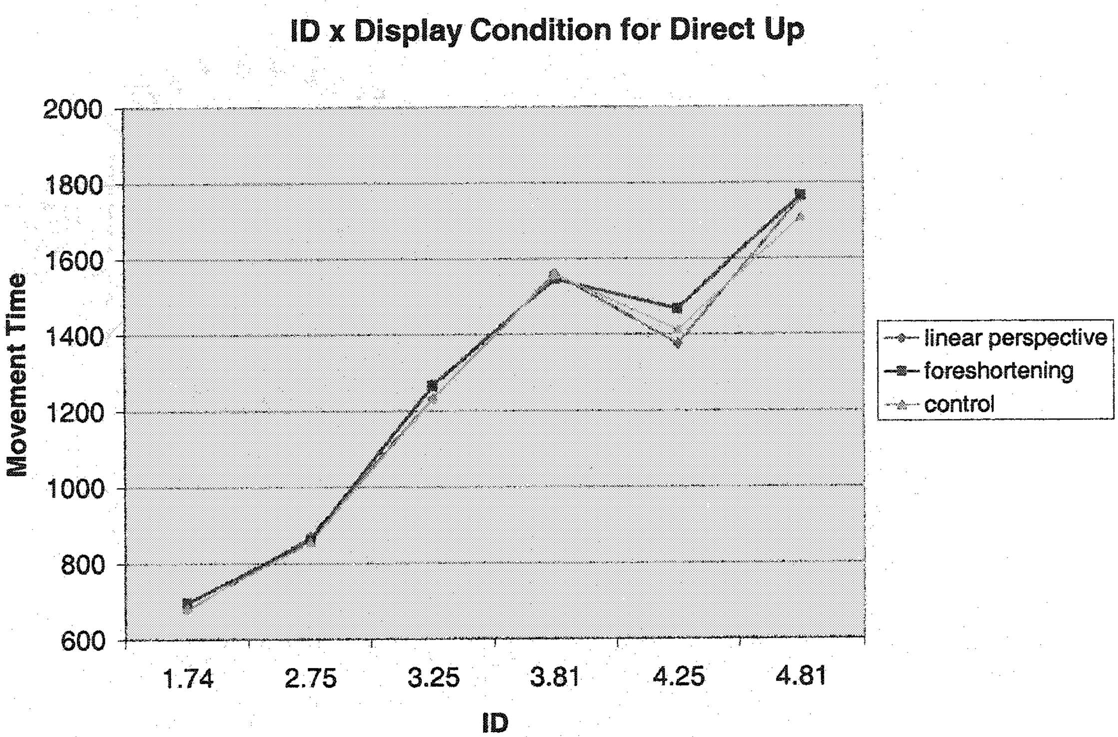

Figure 4. Mean movement times in milliseconds for three display conditions (linear perspective, foreshortening, and control) at six indices of difficulty for direct up (congruent combination of depth cue direction up and movement up).

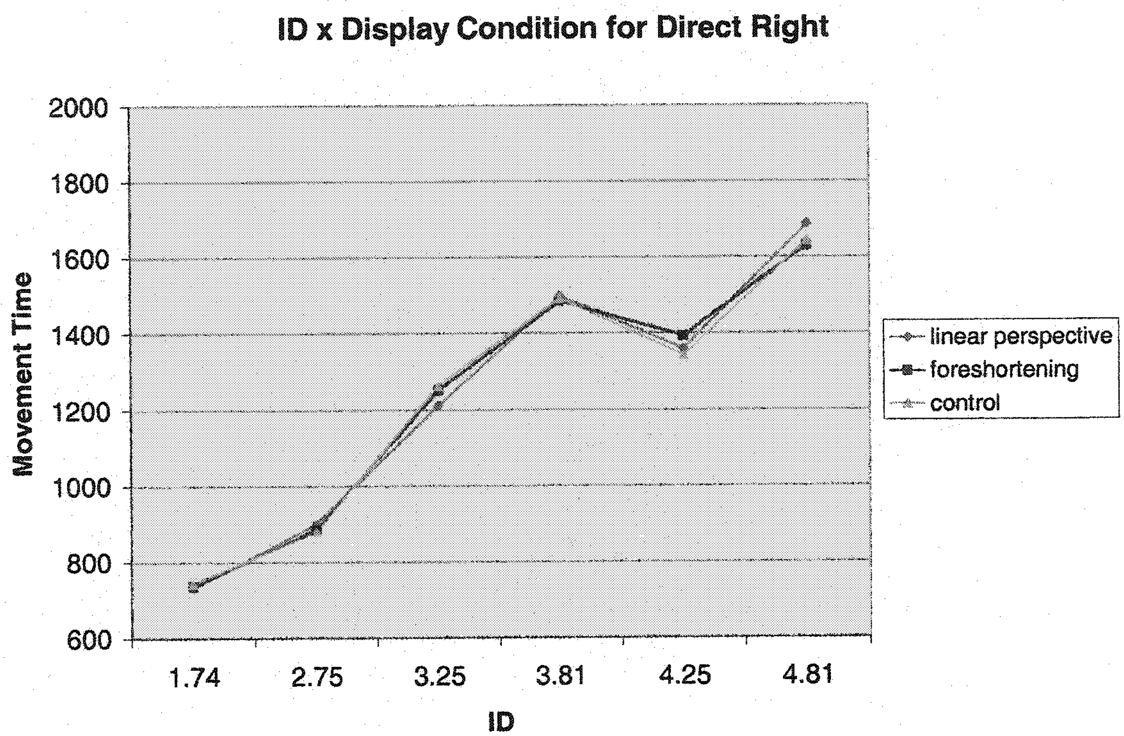

Figure 5. Mean movement times in milliseconds for three display conditions (linear perspective, foreshortening, and control) at six indices of difficulty for direct right (congruent combination of depth cue direction right and movement right).

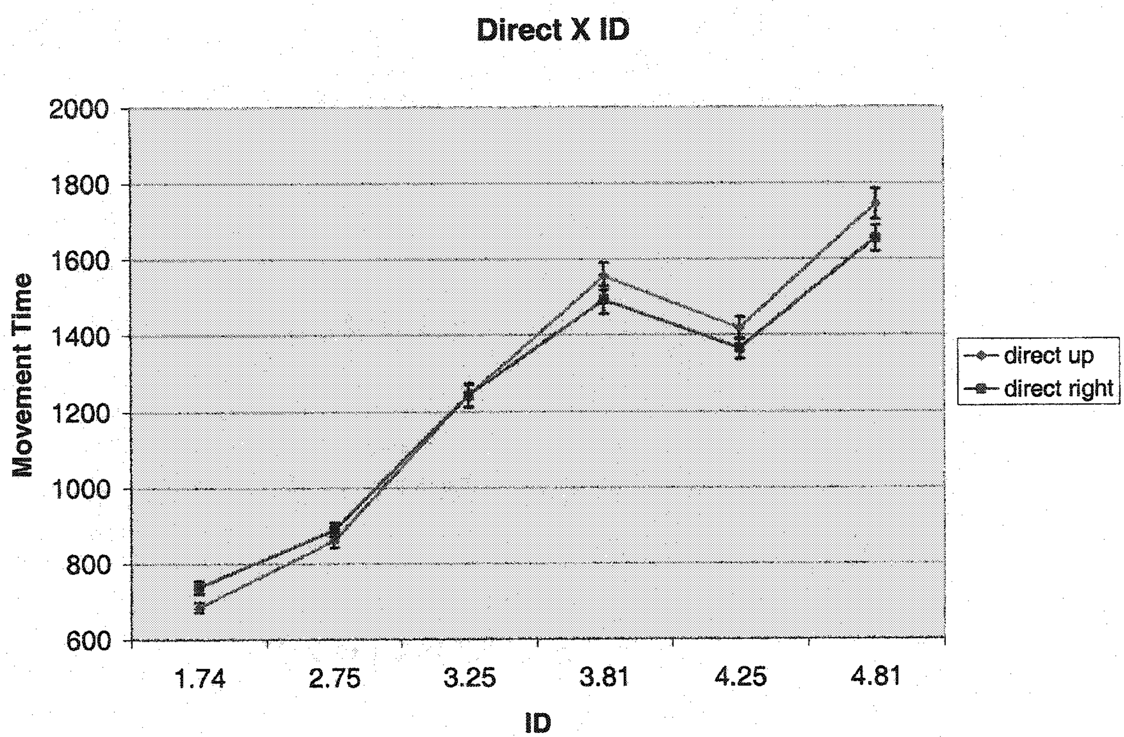

Figure 6. Mean movement times in milliseconds for all six indices of difficulty for direct up (congruent combination of depth cue direction up and movement up) and direct right (congruent combination of depth cue direction right and movement right). Vertical bars are equal to +/- one standard error of the mean.

right) x 2 (depth cue direction: converging right, converging upward) x 6 (indices of difficulty) within subjects analysis of variance. In the analysis, we used only the data from the experimental displays for linear perspective and foreshortening without the control condition because, without the cues to depth, movements in the control condition were always congruent with the display. In our analysis, it was expected that the differences in the geometries of the experimental displays would affect movement times when based on the direction of movement relative to the depth cue direction.

Our analysis showed a significant three-way interaction among display condition, depth cue direction, and movement direction [$F(1,31) = 9.63$, $p<.01$]. Post-hoc analyses showed, however, that the difference was not in the expected direction of movement for the corresponding depth cue direction. Figure 7 shows that only the linear perspective display pointed in a rightward direction showed a significant difference between movements up ($M = 1291.59$) and movements right ($M = 1231.02$). There were no significant differences in movements up and right for foreshortening (see Figure 8). Therefore, our hypotheses that movements congruent with the depth cues would show greater movement times than movements orthogonal to the display, and that movement times in the foreshortening condition would be greater than linear perspective, were not supported.

Discussion

Our ability to perceive and then react to our environment is an important skill. In many real world situations, it is necessary to perceive and identify objects and then control a motor movement such as pointing on a visual display in order to capture a

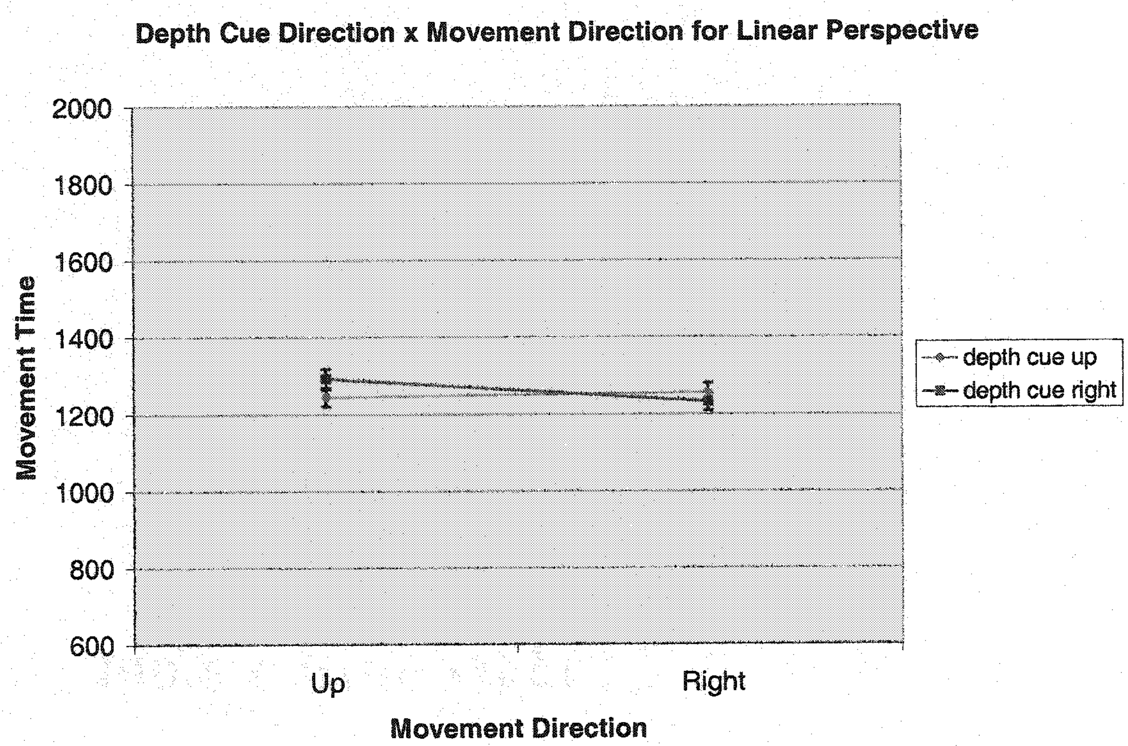

Figure 7. Mean movement times in milliseconds for movement up and right for both depth cue directions (depth cue up and depth cue right) for linear perspective displays. Vertical bars are equal to +/- one standard error of the mean.

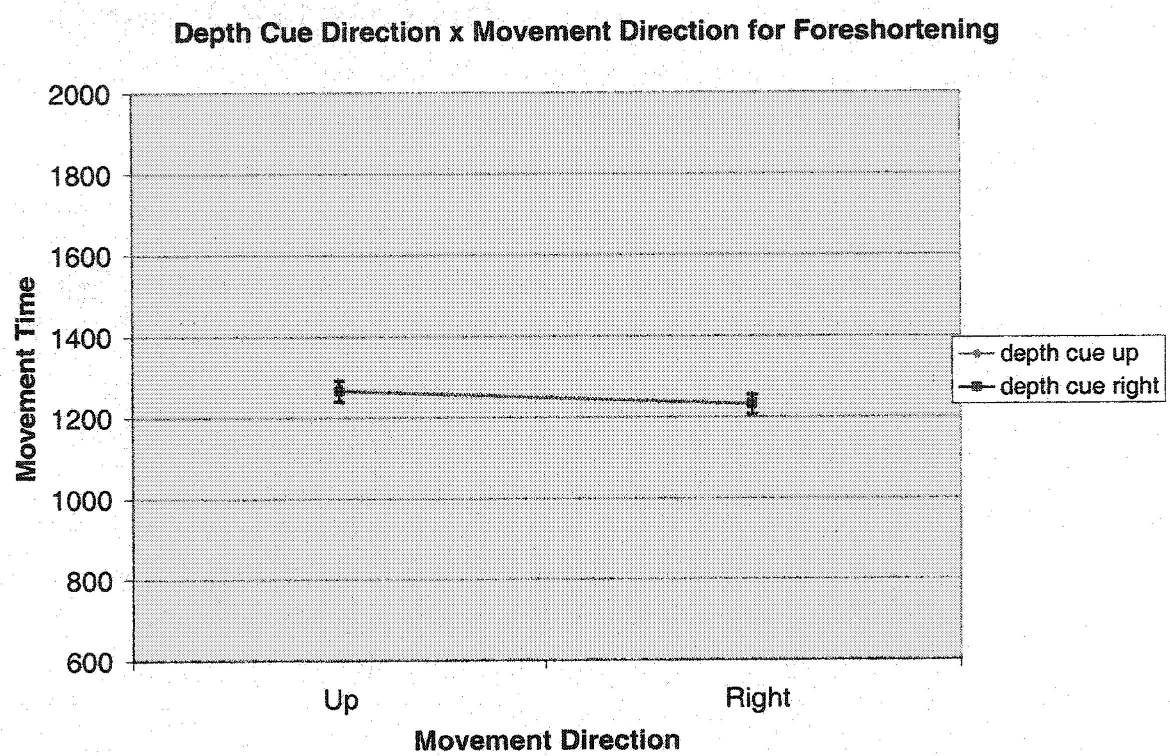

Figure 8. Mean movement times in milliseconds for movement up and right for both depth cue directions (depth cue up and depth cue right) for foreshortening displays. Vertical bars are equal to +/- one standard error of the mean. Also note, the curve for the depth cue up condition is obscured by the curve for the depth cue right condition because the means are identical.

target. In the present study, we explored the relationship between 3-D depth cues and the dynamics of pointing to a target within the visual display for a multitude of size and distance ranges.

As we examined the data as it related to the question of whether we perceive objects distally or proximally in a 3-D display, we found that the motor movements did not seem to be captured by the perceptual cues. Although previous research (Raddatz, Uhlarik, & Jordan, 2001) reported evidence of size constancy in displays very similar to the ones used in our study, our results indicated that the depth cues did not affect the motor movement involved in capturing the target in our visual displays. It is possible that the perceptual displays used in our study were not strong enough to capture depth and therefore the movements were unaffected. It may also be that the motor movements in this task followed more closely with the neuropsychological studies that suggest that perception and action are processed in separate areas of the brain and therefore the movement portion of the task is not affected by the perception of the depth cues.

Additionally, the movements congruent with the 3-D cues did not seem to differ from movements orthogonal to the displays. If the 3-D cues were adding perceptual depth to the movement equation, then we would have expected movements congruent to the depth plane to be longer than movements incongruent to the display. Furthermore, Gillam (1995) suggests that linear perspective and foreshortening have different depth cue geometries. However, the movements in the present study do not seem to be affected by the visual displays. Thus, our data did not support our expectation that movement times for the foreshortening condition would be longer based on the assumption that perceptual distance falls off as $1/d^2$ within the depth dimension. In linear perspective, we expected the movement times to be greater in the congruent condition, but, again, our data did not support this hypothesis. The depth cues did not appear to have an effect on the motor movements.

Our research would seem to suggest that there is a dissociation between the visual perception of objects in a 2-D virtual array, and the motor movements involved in pointing to or acquiring targets. This is consistent with the neuropsychological studies reviewed by Goodale and Milner (1992) that suggest two separate pathways for visual perception of objects, and the motor movements required to reach or acquire those objects. Although the guidance of motor movements found in many of the studies of the dissociation between perception and action focuses primarily on physical reaching or grasping, our study examined the effects on virtual pointing tasks. However, our data indicate a similar conclusion to the grasping studies (Goodale & Milner, 1992; Marotta, Behrman, & Goodale, 1997), that the visual system does not capture the motor movement.

While the data do indicate a dissociation between the visual perception of objects in a 2-D array and the corresponding motor movements to capture those objects, caution must be used in making too strong a conclusion based on a null result. It could be that movement behavior is influenced by display properties in stimuli similar to those we used but that either our choice of control devices or our displays worked against detecting that influence.

One limitation of our study was that our movement times did not adhere to the normal Fitts' Law model that, as the index of difficulty increases, so too, should the movement time. Although Fitts' Law has proved to be an acceptable model for two- and three-dimensional target acquisition tasks (Epps, 1996; Kabbash & Buxton, 1995; Langolf, Chaffin, & Foulke, 1976), the data from the present study did not follow the speed-accuracy trade off for our indices of difficulty. There was an anomaly among the fourth (3.81) and fifth (4.25) index of difficulty where the mean movement time was longer for the fourth index of difficulty as compared to the fifth. We found that movement times followed more closely with the actual distance from cursor to target, such that targets that were farther from the cursor took longer to acquire, regardless of the target size and corresponding index of difficulty. In order to assess the lack of fit of the movement times to Fitts' Law, Arsintescu (in progress) is conducting a similar experiment with a wider range of sizes and distances (ID's). It may also be beneficial to explore the possibility of using a modified version of the Fitts' Law model. Some researchers suggest that 2-D (or 3-D) movement studies using a modified version of Fitts' Law show a better fit to the model (Card, English, & Burr, 1978; MacKenzie, 1992; So, Chung, & Goonetilleke, 1999).

Future studies should address the issue of the depth cue displays to ensure that they have a compelling view to depth and, therefore, capture size constancy. We would also suggest comparing different cursor control devices. Although research suggested that the trackball was an acceptable device (Epps, 1986), it may be that a mouse or joystick may capture the interaction of the visual perception and the motor movement more accurately.

In summary, although our data did not follow the hypotheses, we would suggest that additional research be conducted using similar visual cues and assessing the motor movements involved in pointing to or capturing targets in 2-D displays. We need to increase our understanding of the interactions of visual perception and guided actions using 3-D cues to depth within 2-D virtual arrays, especially if we are to create displays that are an aid to those using them, such as the air traffic controller monitoring aircraft or the physician manipulating a telerobotics device during microsurgery.

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Appendixes

Appendix A

Consent Form

San José State
UNIVERSITY

College of Social Sciences
Department of Psychology
One Washington Square
San José, CA 95192-0120
Voice: 408-924-5600
Fax: 408-924-5605
E-mail: psych@email.sjsu.edu

AGREEMENT TO PARTICIPATE IN RESEARCH AT SAN JOSE STATE UNIVERSITY

Responsible Investigators: Audra Ruthruff, MA in Psychology candidate and Kevin Jordan, Professor of Psychology

I have been invited to participate in research on the perception of visual stimuli in an information display. There will be a single session to the experiment, lasting less than one hour. I will receive one hour of credit toward my Psychology 001 research requirement based on my participation. The possible benefits I might gain from my participation include learning more about how the visual system processes size and distance information in a visual display. The possible risk is minimal eye strain equivalent to what might occur from 40 minutes work on a computer. I understand that my participation in the experiment is voluntary.

If I decide to participate, I will be asked to use a trackball to move a cursor into the boundaries of a target specified on the computer display. There will be over 200 hundred of these movements for me to make. However, the experiment is quite fast-paced and the entire procedure will take less than 50 minutes.

Data gathered from this study will be stored on a computer disk which no one but the experimenter will be able to access. In case the results of this study are published, any information that is obtained from me in connection with this study and that can be identified with me will remain confidential.

My decision to participate or not participate will not in any way prejudice my future relations with San Jose State University. If I decide to participate, I am free to withdraw my consent and to discontinue my participation at any time without penalty and without any loss of the one hour credit toward my Psychology 001 research requirement for participation in this experiment. I may quit the experiment at any time. No service of any kind, to which I am otherwise entitled, will be lost or jeapordized if I choose not to participate.

If I have any questions, I may ask them prior to the start of the experiment. If I have any questions after the experiment, I may contact Dr. Jordan at 924-5626 or drop by DMH 342. If I have any complaints about the procedure, I may contact Dr. Robert Pellegrini, Psychology Department Chair at 924-5600 (DMH 157). For questions about research participants' rights, or in the event of research-related injury, I may contact Dr. Nabil Ibrahim (Associate Academic Vice President for Graduate Studies) at 924-2480.

I am making a decision whether or not to participate. My signature indicates that I have decided to participate having read the information provided above. I have received a copy of this consent form for my records.

SIGNATURE________________________ DATE__________

PRINTED NAME__________________

SOCIAL SECURITY #______________

SIGNATURE____________________
(Investigator)

Appendix B

Human Subjects Approval Form

San José State
UNIVERSITY

Office of the Academic Vice President

Associate Vice President Graduate Studies and Research

One Washington Square
San José, CA 95192-0025
Voice: 408-924-2480
Fax: 408-924-2477
E-mail: gstudies@wahoo.sjsu.edu
http://www.sjsu.edu

To: Audra J. Ruthruff
5698 Lilac Blossom Lane
San José, CA 95124

From: Nabil Ibrahim,
AVP, Graduate Studies & Research

Date: October 1, 2002

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

" Effects of Perceptual Depth Cues on
Movement Time in a Target Acquisition Task."

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to all data that may be collected from the subjects. The approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Nabil Ibrahim, Ph.D. immediately. Injury includes but is not limited to bodily harm, psychological trauma, and release of potentially damaging personal information. This approval for the human subjects portion of your project is in effect for one year, and data collection beyond October 1, 2003 requires an extension request.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services that the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.